Horizontal Product Differentiation in Auctions and Multilateral Negotiations[*]

Charles J. Thomas
Department of Economics
Clemson University
222 Sirrine Hall
Clemson, SC 29634
E-mail: *cjt@clemson.edu*

Bart J. Wilson
Interdisciplinary Center for Economic Science
George Mason University
4400 University Drive, MSN 1B2
Fairfax, VA 22030
E-mail: *bwilson3@gmu.edu*

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Abstract: We experimentally compare first-price auctions and multilateral negotiations after introducing horizontal product differentiation into a standard procurement setting. We find that the two institutions yield the buyer the same surplus, a difference from prior findings with homogeneous products that results from differentiation's influence on the sellers' pricing behavior. In particular, we observe that introducing product differentiation intensifies price competition among the sellers in some treatments, and has no effect in others, which contrasts with the conventional wisdom that product differentiation softens competition.

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1. Introduction

A fundamental goal of economics is to understand the variety of means through which voluntary exchange is conducted, such as the bargaining, conducting of auctions, and posting of prices that are used to arrange for the trade of goods and services. We see variants emerge that blur the lines between what previously appeared to be distinct types of exchange methods.[1] In fact, some of these new methods themselves become "goods and services," with their designers applying for patent protection and being hired to organize markets.[2]

Improving institutional design is an important reason for trying to understand the workings of different exchange methods, because doing so allows one to make a more informed choice amongst them, using metrics such as profitability, efficiency, or perceptions of fairness. For example, the simultaneous ascending auction used to allocate U.S. radio spectrum in the 1990s is widely held to have been enormously successful in generating substantial government revenues and an efficient aggregation of complementary licenses.[3]

In this paper we compare two commonly used means of exchange, auctions and multilateral negotiations. Auctions have been studied extensively by economists, and are used to allocate products such as electric power, pollution rights, art, and government securities.[4] Multilateral negotiations combine features of auctions and bilateral bargaining, although they have received much less academic attention than have those two exchange methods.[5] In them, a buyer solicits offers from multiple sellers and then plays the sellers off one another to receive

[1] For example, consider the "Anglo-Dutch" auction described in Klemperer [2002], the simultaneous ascending auction, used to sell U.S. radio spectrum, described in Milgrom [2000], or the "Buy It Now" feature in auctions on E-Bay.
[2] Companies such as MercExchange, Inc. and Ozro, Inc. have obtained patents covering online auctions and electronic negotiations, respectively. Economists such as Paul Milgrom and Larry Ausubel also hold patents on different auction designs.
[3] See McAfee and McMillan [1996].
[4] See Wolfram [1998], Cason [1995], Milgrom and Weber [1982], and McAfee and McMillan [1987].
[5] See Thomas and Wilson [2002, 2005], along with related work in Cason, et al [2003].

additional concessions. Among other settings, they are used in industrial procurement, high-end job markets, and the purchase of contractors' services and automobiles.

One thing that seems clear from previous analyses of trading mechanisms is that their performance depends on characteristics of the strategic environment in which they are employed. For example, Klemperer [2002] argues that one size does not fit all in auction design, with factors such as the number of potential bidders, their relative size or importance, and the likelihood of collusion meriting careful consideration. Theoretical arguments illustrate that it matters who makes offers in bilateral bargaining when there exists one-sided private information about costs or values.[6]

With the preceding points in mind, in this paper we use the experimental method to investigate how the nature of product characteristics affects institutional performance. Specifically, we evaluate how introducing horizontal product differentiation into a standard procurement environment affects the outcomes of both auctions and multilateral negotiations. We consider horizontal differentiation for two reasons. First, although auctions and multilateral negotiations typically are analyzed under the assumption that bidders are homogeneous from the auctioneer's perspective,[7] in procurement settings it frequently is the case that the buyer has different, privately known preferences over non-price attributes of the sellers' products. Therefore, it seems worthwhile to investigate behavior in this environment. Second, previous research has found that some auction formats yield the buyer greater surplus than do multilateral negotiations, which leaves open the question of why multilateral negotiations are such a commonly used means of exchange. One reason may be that real strategic environments differ in important dimensions from the settings that so far have been examined. Differentiation may

[6] Kennan and Wilson [1993] provides an excellent overview of bargaining with private information.
[7] For example, see Milgrom and Weber [1982], McAfee and McMillan [1987], Wolfram [1998], Waehrer and Perry [2003], and Thomas and Wilson [2002, 2005].

be one such dimension, and when it is present we hypothesize that the dynamic nature of multilateral negotiations allows the buyer to profitably exploit its privately known preferences in a way that one-shot auctions do not. If so, then in this setting the buyer may receive relatively greater surplus from using negotiations than from using auctions.

There are several questions of interest once product differentiation is introduced into the strategic environment. First, how do the outcomes of auctions and multilateral negotiations compare when there is product differentiation? We find that both institutions yield the buyer the same expected surplus, which contrasts in part with prior findings involving homogeneous products. Thomas and Wilson [2002] find that auctions yield higher surplus than do multilateral negotiations with two sellers, but yield the same surplus with four sellers. The present findings suggest that having privately known preferences over the sellers' products allows the buyer to extract relatively more surplus from the sellers when negotiating than when using an auction, at least when there are few sellers.

Second, can we determine how these changes in the institutions' relative performance occur? That is, from the buyer's perspective, does introducing product differentiation improve the negotiations' performance, degrade the auctions' performance, or lead to some other change? To address this issue we measure the intensity of competition among the sellers, and we find a surprising result. With two sellers following the introduction of product differentiation, price competition in both institutions is intensified, albeit to different extents. This finding suggests that the buyer benefits from having privately known preferences, and this benefit is greater in the negotiations. With four sellers there is no discernible change in the intensity of price competition in either institution. While the latter finding's difference from the former simply may reflect that the settings with four sellers are intensely competitive regardless of product

characteristics, both findings contrast with the conventional wisdom that product differentiation softens competition among sellers.

We introduce product differentiation by considering a linear random utility model that is standard within the discrete-choice framework,[8] with the modification that each seller's production cost is assumed to be that seller's private information. The existence of private information about the buyer's values and the sellers' costs contributes to the main difference between the auctions and the negotiations, namely that the communication allowed by the negotiations provides opportunities for the buyer and the sellers to signal or to misrepresent their private information in an attempt to secure a larger portion of the gains from trade.[9]

The framework we consider also is similar to the one used in analyses of "scoring" auctions, as in Che [1993]. In a typical analysis, sellers make price-quality offers to a buyer who evaluates those offers according to some scoring rule. The main difference between our approach and the literature on scoring auctions is that we assume that the sellers do not tailor their product to a particular buyer. Which approach is more applicable is an empirical matter specific to the market in question.

2. Experimental Design and Procedures

Consider a setting in which sellers producing horizontally differentiated products compete to fulfill a contract for a single risk-neutral buyer. The buyer has privately known preferences for each seller's product, and each seller has privately known production costs. The distributions from which the values and the costs are drawn are commonly known to all market participants. We pair two treatments, one with 16 first-price auctions and one with 16

[8] See Anderson, de Palma, and Thisse [1992] for a comprehensive treatment of discrete choice models.
[9] Similar incentives are present in bilateral bargaining settings with private information. See Fudenberg and Tirole [1983] for an early treatment.

nonverifiable multilateral negotiations. We vary these two treatments by changing the number of sellers from two per buyer to four per buyer, which yields four treatments in total.

For each of the four treatments we have four groups of subjects, which we also refer to as sessions. Each subject is assigned a specific role in a specific group for the duration of the experiment. A seller's characteristics consist of 16 privately known random cost draws from the Uniform distribution on the support [0, 600] (in cents), one for each time period. Of the eight groups with four sellers, seller i (i = 1, 2, 3, 4) has the same cost draws across groups. Of the eight groups with two sellers, seller i (i = 1, 2) has the same cost draws across groups. Moreover, the costs of sellers 1 and 2 in the two-seller treatment are the same as the costs of sellers 1 and 2 in the four-seller treatment. This reduces the variation across subjects and consequently tightens the standard errors of our estimates.

The buyer's characteristics consist of 16 sets of privately known random preference draws from the Uniform distribution on the support [300, 900]. Each set consists of either two or four draws for each time period, depending on the number of sellers. Analogously to the sellers' costs, the buyers in all 16 groups have the same preference draws for seller i (i = 1, 2, 3, 4).

The first-price auction proceeds with each seller simultaneously submitting a secret price offer. The seller offering the buyer the highest surplus is awarded the contract at the price that it offered, provided that surplus exceeds 0. The buyer's surplus is $V_w - p$, where V_w is the buyer's value for the winning seller's product, and p is the transaction price. The winning seller's profit is $p - c_w$, where c_w is the winning seller's cost. All other sellers receive 0.

The nonverifiable multilateral negotiation proceeds with each seller simultaneously submitting a secret price offer. If the buyer accepts one of the offers, then the negotiation concludes and the transaction price is the price offered by the winning seller. Payoffs are

determined as in the auction setting. If the buyer rejects all of the offers, then the buyer can engage in non-binding text messaging with each seller over the computer network. The buyer cannot credibly reveal to a seller his preferences or the offers he has from other sellers. The sellers can respond to these communications by making lower price offers, the buyer can accept or reject these new offers, and so on. [10]

The only significant difference between the strategic environment in this experiment and the one reported in Thomas and Wilson [2002] is the introduction of product differentiation. In particular, in Thomas and Wilson [2002] the buyer's value for each seller's product was commonly known to be 600, while here the unbiased *expectation* of the buyer's value is 600. Therefore, a transaction between the buyer and a given seller has the same expected total surplus in both environments. However, as we will describe later, introducing product differentiation increases the expected value of the highest total surplus.

Participants, undergraduate students recruited from George Mason University at large, received $5 for showing up on time, plus their salient earnings. In the four-seller sessions, the buyers' exchange rate was US$1 for 7 experimental dollars, and the sellers' exchange rate was US$1.50 for 1 experimental dollar. In the two-seller sessions, the exchange rates were 4 and 2 experimental dollars for each US$1, respectively. In addition to the $5 show-up payment, the average subject's earnings were $19.17. The average session lasted ninety minutes.

3. Experimental Results

For each period we observe the transaction price, the buyer's value for each seller's product, each seller's cost, each seller's offer in the auctions, and each seller's initial and

[10] See Thomas and Wilson [2002] for further design details. The present experiment closely follows the design in that paper, with the main difference being the introduction of the buyer's preferences.

subsequent offers in the multilateral negotiations. We analyze the data using a linear mixed-effects model for repeated measures,[11] and we pool the data from the present experiment with the data from Thomas and Wilson [2002] that considers homogeneous products.[12] Combining the data permits parsimonious comparisons across institutions within a differentiation regime, and within institutions across differentiation regimes.

We focus our attention on the buyer's surplus rather than on the transaction price, because prices do not provide a meaningful way to compare settings with and without product differentiation, from the perspective of the participants' payoffs.[13] Moreover, even across-institution comparisons using prices may be misleading in settings with product differentiation. For example, auctions may lead to higher transaction prices but higher buyer's surplus, if in the auctions the buyer more frequently purchases from the seller whose product has the highest intrinsic value. In that case the buyer would prefer the exchange mechanism with higher prices.

Table 1 reports the model's regression results, with the buyer's surplus as the dependent variable. The treatment effects (*Two* vs. *Four* Sellers, Nonverifiable Multilateral *Negotiation* vs. *First-Price Auction*, and *Differentiation* (*D*) vs. *Homogeneous* Products) and the two- and three-term interaction effects from a 2^3 design are modeled as (zero-one) fixed effects. The 32 independent sessions are modeled as random effects, e_i. Following Thomas and Wilson [2002], we control for across-period surplus variation by including period-specific deviations of the highest and second-highest surpluses from their theoretical expected values. Those deviations

[11] See Longford [1993] for a description of this technique commonly employed in experimental sciences.
[12] In particular, we use the data from the first twelve periods of the experiment described in Thomas and Wilson [2002]. That experiment used a crossover design, and so the outcomes following a change from one institution to another are not directly comparable to the outcomes in the present experiment.
[13] The results in Thomas and Wilson [2002] regarding transaction prices with homogeneous products can be easily translated into surplus terms, because the buyer's value for all sellers' products is a known constant.

are denoted by s_1 and s_2.[14] This formulation permits us to capture each treatment's expected buyer's surplus solely in the treatment coefficient, because on average $s_1 = s_2 = 0$. Specifically, we estimate the model

$$\begin{aligned}\pi_{ij}^{B} = {} & \mu + e_i + \beta_1 Two_i + \beta_2 Negotiation_i + \beta_3 Two_i \times Negotiation_i + \\ & \beta_4 s_{1ij} + \beta_5 s_{1ij} \times Two_i + \beta_6 s_{1ij} \times Negotiation_i + \beta_7 s_{1ij} \times Two_i \times Negotiation_i + \\ & \beta_8 s_{2ij} + \beta_9 s_{2ij} \times Two_i + \beta_{10} s_{2ij} \times Negotiation_i + \beta_{11} s_{2ij} \times Two_i \times Negotiation_i + \\ & \beta_{12} D + \beta_{13} D \times Two_i + \beta_{14} D \times Negotiation_i + \beta_{15} D \times Two_i \times Negotiation_i + \\ & \beta_{16} D \times s_{1ij} + \beta_{17} D \times s_{1ij} \times Two_i + \beta_{18} D \times s_{1ij} \times Negotiation_i + \beta_{19} D \times s_{1ij} \times Two_i \times Negotiation_i + \\ & \beta_{20} D \times s_{2ij} + \beta_{21} D \times s_{2ij} \times Two_i + \beta_{22} D \times s_{2ij} \times Negotiation_i + \beta_{23} D \times s_{2ij} \times Two_i \times Negotiation_i + \varepsilon_{ij}\end{aligned}$$

where π_{ij}^{B} denotes the buyer's surplus in period j of session i, with $e_i \sim N(0, \sigma_1^2)$ and $\varepsilon_{ij} \sim N(0, \sigma_{2,i}^2)$.[15] We accommodate heteroskedastic errors by session when estimating the model via maximum likelihood.

Estimates of the treatment effects are easy to compute with this specification. The buyer's expected surplus is μ in a four-seller first-price auction with homogeneous products, $\mu + \beta_{12}$ in a four-seller first-price auction with differentiated products, $\mu + \beta_2$ in a four-seller non-verifiable multilateral negotiation with homogeneous products, and so forth. Across-treatment surplus differences, and differences-in-differences, also are easy to compute.

For comparison purposes, we begin by restating a central finding from Thomas and Wilson [2002] regarding the buyer's surplus with homogeneous products.

[14] With homogeneous products and two sellers, the expected values of the highest and second-highest surpluses are 400 and 200. With four sellers the expected values are 480 and 360. With horizontally differentiated products and two sellers, the expected values are 440 and 160. With four sellers the expected values are 554.524 and 376.429.
[15] It is important to note that the linear mixed effects model for repeated measures treats each *session* as one degree of freedom with respect to the treatments.

Finding 0**:** *Consider the setting with homogeneous products. With two sellers the buyer's surplus when using multilateral negotiations is significantly lower than when using first-price auctions. In contrast, with four sellers the buyer's surplus is statistically indistinguishable when using multilateral negotiations and first-price auctions.*

Evidence**:** The sum of the coefficients on *Negotiation* and *Two* × *Negotiation* on the left side of Table 1 represents the amount by which the negotiation treatment changes the buyer's surplus relative to first-price auctions, with two sellers. The negotiation treatment significantly decreases the buyer's surplus by 104.6 (= -3.1 - 101.5) experimental cents below its level in first-price auctions (p-value = 0.0001). With four sellers the point estimate of the negotiation treatment is economically small (-3.1) and statistically insignificant (p-value = 0.8746). ■

Thomas and Wilson [2002] argue that auctions and negotiations differ with two sellers because, when negotiating, the buyer is unable to continue extracting additional discounts from the low-cost seller in those instances in which that seller's rival has high costs. With four sellers the buyer's ability presumably is less relevant, because the difference between the lowest and second-lowest costs on average is smaller than when there are only two sellers.

Turning to differentiated products, we hypothesize that multilateral negotiations may perform relatively better than do first-price auctions when the buyer has privately known preferences for each seller's product, because the auctions are likely to be less efficient than they are in the case of homogeneous products.[16] Reduced efficiency in the auctions implies there are lost gains from trade, and it is possible that the dynamics inherent in the multilateral negotiations

[16] First-price auctions are predicted to be 100% efficient with homogeneous products in our setting. To see from a theoretical perspective why first-price auctions might be inefficient with differentiated products, suppose that sellers set their prices according to a function that is strictly increasing in their privately known production costs. The winning seller will not necessarily be the one with the largest difference between the buyer's preference and the seller's cost, because equilibrium price-setting functions likely increase less than one for one with the seller's cost.

will allow those gains from trade to be exploited. We begin by evaluating the buyer's surplus across institutions when there exists product differentiation.

Finding 1**:** *Consider the setting with horizontally differentiated products. With a given number of sellers, the buyer's surplus is statistically indistinguishable when using multilateral negotiations and first-price auctions.*

Evidence**:** The estimates in Table 1 provide the evidence for this finding. With two sellers, the difference between the buyer's surplus in the negotiations and the auctions is 12.4 (= -3.1 - 101.5 + 4.7 + 112.3) and insignificant (p-value = 0.5416), as given by the sum of the coefficients on *Negotiation*, *Two* × *Negotiation, Differentiated* × *Negotiation*, and *Differentiated* × *Two* × *Negotiation*. With four sellers, the difference is 1.6 (= -3.1 + 4.7) and insignificant (p-value = 0.9352). This difference is the sum of the *Negotiation* and *Differentiated* × *Negotiation* coefficients. ■

Unlike with homogeneous products, buyers facing two sellers do not receive higher surplus with first-price auctions than with multilateral negotiations. Hence we conclude that introducing product differentiation leads to the negotiations performing relatively better for the buyer, which suggests that the buyer can better exploit its privately known preferences as a result of the communications allowed by the multilateral negotiations. Moreover, this finding is consistent with our hypothesis that multilateral negotiations' prevalence stems in part from aspects of strategic environments that are not present in earlier analyses.

While Finding 1 illustrates the relative effectiveness of auctions and negotiations, considering how that change comes about may deepen our understanding of how product

differentiation changes behavior in the two institutions. That is, while we know that introducing product differentiation with two sellers causes the negotiations to become relatively more competitive than the auctions, is this due to more intense competition in the negotiations, less intense competition in the auctions, or some other change?

In the next finding we address this issue by measuring the intensity of competition in each treatment. While there are many ways one might attempt to measure competition, care must be taken to account for changes that arise simply because expected surplus is greater in the settings with product differentiation, or from other effects of changing the strategic environment.

Our measure of the intensity of competition includes the buyer's realized surplus in a period (π^B) as a fraction of the total surplus possible that period (S_1). Identifying what portion of the available surplus the buyer receives, rather than just the amount of surplus received, accounts for increases in the buyer's surplus that may occur solely because greater total surplus is available with product differentiation. That is, the buyer's surplus may increase even if the sellers become less competitive, with the end result that the buyer receives relatively less of the available surplus. We use the maximum possible surplus rather than actual realized surplus (the sum of the buyer's and sellers' surplus) to account for efficiency losses that may occur. With this approach, two transactions with the same buyer's and sellers' surplus will have different measures of competition if one transaction is more efficient than the other. That is, we characterize an efficiency loss as a symptom of decreased competition among the sellers.

We then subtract from $\frac{\pi^B}{S_1}$ the predicted buyer's surplus in a period as a fraction of total surplus possible that period, when using an efficient exchange mechanism for which competition among the sellers does not change across treatments. Specifically, we use the buyer's surplus that would emerge in a "second-surplus" auction in which the sellers have a dominant strategy of

setting their price equal to their cost in both the homogeneous product and differentiated product settings. To summarize then, the dependent variable for a specific period's values and costs is $\frac{\pi^B - S_2}{S_1}$, where S_2 is the second-highest level of surplus possible.

The reason for using the preceding approach is to account for changes in the buyer's surplus that emerge simply through changes in the strategic environment that do not lead to changes in the sellers' behavior. To illustrate the issue, consider a duopoly procurement setting with homogeneous products in which the sellers' costs are uniformly distributed from 0 to 600, the buyer's value for the sellers' product is 1000, and first-price auction rules are used. In equilibrium, the expected price equals the expected value of the second-lowest cost, 400. The average buyer's surplus is 75 percent of the average available total surplus. If we modify the setting by shifting the costs up by 300, then the sellers' equilibrium price offers also shift up by 300, so that the expected price is now 700. While there arguably is no change in the intensity of competition between the sellers, the average buyer's surplus is only 60 percent of the average available total surplus. By subtracting off the buyer's surplus in a second-price auction (which is a specific version of a second-surplus auction when products are homogeneous), then in both settings the comparative measure of competition is 0.

***Finding 2*:** *Consider moving from homogeneous products to horizontally differentiated products, holding fixed the number of sellers and the institution. With two sellers the intensity of competition increases when using multilateral negotiations, and to a lesser extent when using first-price auctions. With four sellers there is no change in the intensity of competition when using multilateral negotiations or first-price auctions.*

***Evidence*:** The estimates in Table 2 provide the evidence for this finding. With two sellers, introducing differentiation in multilateral negotiations significantly increases our competition measure by 0.771 (= 0.064 + 0.495 + 0.000 + 0.212) (p-value < 0.0001), while doing so in first-price auctions significantly increases it by 0.559 (= 0.064 + 0.495) (p-value < 0.0001). The difference in the change between the institutions is 0.212 and is significant (p-value = 0.0146). With four sellers, introducing differentiation in multilateral negotiations insignificantly increases our competition measure by 0.064 (= 0.064 + 0.000) (p-value = 0.1322), while doing so in first-price auctions also insignificantly increases it by 0.064 (p-value = 0.1241). The changes with four sellers in the negotiations and the auctions are statistically indistinguishable. ■

Finding 2 describes the manner in which the introduction of horizontal product differentiation equalizes the buyer's surplus across institutions. Surprisingly, introducing differentiation increases or leaves unchanged the intensity of competition among the sellers, which contrasts with the conventional wisdom that product differentiation softens competition.

This intriguing result can potentially be explained by recognizing that the buyer may receive informational rents due to its private information about its preferences for the different sellers' products. We illustrate this possibility in the following simple monopoly model that is based on our present strategic environment, rather than by attempting to solve a less tractable duopoly model.

Consider a monopolist whose production cost is uniformly distributed from 0 to 600, and who makes a take-it-or-leave-it price offer to a single buyer. If the buyer's value for the seller's product is commonly known to be 600, then the monopolist's optimal price is 600, its expected payoff is easily shown to be 300, and the buyer's expected payoff is 0.

If the buyer's value for the seller's product instead is privately known and varies uniformly from 300 to 900, then the monopolist's optimal price is $450 + 0.5c$ when its cost is c. Compared to the full-information setting, the monopolist sets a lower price when it has low costs, and sets a higher price when it has high costs. One can show that the monopolist's expected payoff is 162.5, while the buyer's expected payoff is 81.25. The fact that a monopolist experiences a payoff reduction when the buyer's preferences are private information makes it more plausible that duopolists would as well.

Finally, we consider product differentiation's effect on efficiency, because we hypothesized that inefficiency in the first-price auctions may be one avenue through which the negotiations would yield a performance improvement for the buyer. However, efficiency in each period is so consistently high in all sessions that there is insufficient variation to estimate a linear mixed-effects model for the ratio of realized total surplus to maximum available surplus. Therefore, we provide suggestive evidence about efficiency by comparing the expected value of the highest total surplus to the sum of the estimated values of the buyer's surplus and the sellers' surplus. Estimates of the winning seller's surplus are provided in Table 3, using the same linear mixed-effects approach with which we estimated the buyer's surplus in Table 1. These estimates actually reflect the sum of the sellers' surpluses, because losing sellers earn zero.

Table 4 reports the sum of the estimated buyer's surplus and winning seller's surplus as a fraction of the expected maximum total surplus. Efficiency is high in all treatments, and there is no obvious economically significant change from introducing product differentiation. One explanation for the high efficiency levels is the apparently intense competition that exists in all four-seller treatments, and the increased competition in the two-seller treatments following the introduction of product differentiation. With product differentiation, efficiency tends to be

higher the closer the sellers' prices are to their costs, because in such cases the winning seller is more likely to be the efficient trading partner.

The preceding evidence suggests that inefficiency in the first-price auctions when there is product differentiation is not what drives the negotiations' relative performance improvement, but ruling out inefficiency does open up another possibility. With two sellers and homogeneous products, Thomas and Wilson [2002] provided evidence that the surplus difference between the auctions and the negotiations occurred when one seller had particularly low costs and the other seller had high costs. In such cases it appears that the buyer was unable to obtain significant concessions from the low-cost seller in the negotiations. With differentiation our results show that the across-institution difference has disappeared, perhaps because a low-cost seller now is more concerned that it may not be the surplus-maximizing choice. That is, low costs are less of a guarantee that the seller is going to make a sale, because the buyer may have a low intrinsic value for that seller's product and a high intrinsic value for the other seller's product. Therefore, a low-cost seller may be more easily persuaded to offer price concessions when there is differentiation.

4. Conclusion

In this paper we find that introducing product differentiation into a standard procurement setting can change the relative performance rankings of auctions and multilateral negotiations by affecting sellers' price-setting behavior. With two sellers, the buyer's surplus is equal in the auctions and the negotiations when products are differentiated, while surplus in the auctions is higher than in the negotiations when products are homogeneous. With four sellers we find that differentiation leads to no change in the institutions' relative performance rankings, so that

auctions and multilateral negotiations continue to yield the buyer equal surplus. The introduction of differentiation helps to address an issue raised in earlier research that assumed that products were homogeneous: with two sellers first-price auctions outperformed multilateral negotiations from the buyer's perspective, but negotiations are a common means of exchange.

We also investigate how the sellers' behavior changes as we introduce product differentiation, which provides insights into how the institutions' relative performance rankings are influenced. With two sellers we find that competition becomes more intense in both the auctions and the negotiations, perhaps due to a low-cost seller's willingness to offer concessions when faced with uncertainty about whether it is the surplus maximizing trading partner. When the buyer's value is the same for all sellers' products, a low-cost seller is more confident that it will ultimately make the sale. With four sellers there is no change in the intensity of competition. Both findings contrast with the typical intuition from standard oligopoly models, but in part may reflect the inherency of informational rents that accrue to the buyer with differentiated products.

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Table 1. Estimates of the Linear Mixed-Effects Model for Buyer's Surplus

					Dummy Variable for Differentiated × Baseline			
Homogeneous Baseline (Thomas and Wilson, 2002)	Estimate	Std. Error	Degrees of Freedom	*p*-value	Estimate	Std. Error	Degrees of Freedom	*p*-value
Constant	424.5	13.5	400	<0.0001	70.3	19.7	24	0.0016
Two	-104.1	20.4	24	<0.0001†	-31.9	28.4	24	0.2721
Negotiation	-3.1	19.3	24	0.8746	4.7	27.8	24	0.8665
Two × *Negotiation*	-101.5	28.9	24	0.0018	112.3	40.5	24	0.0105
s_1	1.0	0.2	400	<0.0001	0.0	0.2	400	0.9192
s_1 × *Two*	-0.2	0.2	400	0.1804	0.2	0.2	400	0.2317
s_1 × *Negotiation*	0.1	0.2	400	0.6542	0.0	0.3	400	0.9364
s_1 × *Two* × *Negotiation*	-0.6	0.2	400	0.0084	0.4	0.3	400	0.1095
s_2	0.0	0.1	400	0.7652	0.0	0.1	400	0.7868
s_2 × *Two*	0.1	0.1	400	0.3078	-0.1	0.2	400	0.4237
s_2 × *Negotiation*	-0.2	0.2	400	0.3584	0.0	0.2	400	0.8651
s_2 × *Two* × *Negotiation*	0.1	0.2	400	0.5566	0.1	0.2	400	0.7761
			448 Obs.					

†One-sided test.

Table 2. Estimates of the Linear Mixed-Effects Model for Buyer's Surplus as a Fraction of Available Total Surplus, Relative to Competitive Benchmark

					Dummy Variable for Differentiated × Baseline			
Homogeneous Baseline (Thomas and Wilson, 2002)	Estimate	Std. Error	Degrees of Freedom	*p*-value	Estimate	Std. Error	Degrees of Freedom	*p*-value
Constant	0.150	0.028	400	<0.0001	0.064	0.040	24	0.1241
Two	-0.236	0.047	24	<0.0001	0.495	0.068	24	<0.0001
Negotiation	0.000	0.041	24	0.9924	0.000	0.058	24	0.9992
Two × *Negotiation*	-0.176	0.064	24	0.0116	0.212	0.099	24	0.0428
s_1	0.001	0.000	400	0.0001	0.000	0.000	400	0.5530
s_1 × *Two*	-0.001	0.000	400	0.0026	0.001	0.000	400	0.0406
s_1 × *Negotiation*	0.000	0.000	400	0.6550	0.000	0.001	400	0.9263
s_1 × *Two* × *Negotiation*	-0.001	0.001	400	0.0549	0.001	0.001	400	0.2967
s_2	-0.002	0.000	400	<0.0001	0.000	0.000	400	0.5331
s_2 × *Two*	0.002	0.000	400	<0.0001	-0.003	0.000	400	<0.0001
s_2 × *Negotiation*	0.000	0.000	400	0.3406	0.000	0.000	400	0.7788
s_2 × *Two* × *Negotiation*	0.000	0.000	400	0.3356	0.000	0.001	400	0.4873
			448 Obs.					

†One-sided test.

Table 3. Estimates of the Linear Mixed-Effects Model for Winning Seller's Surplus

Homogeneous Baseline (Thomas and Wilson, 2002)	Estimate	Std. Error	Degrees of Freedom	*p*-value	*Dummy Variable for Differentiated × Baseline* Estimate	Std. Error	Degrees of Freedom	*p*-value
Constant	36.5	11.5	400	0.0016	9.7	16.4	24	0.5611
Two	36.7	18.4	24	0.0286 †	-13.3	25.4	24	0.6057
Negotiation	8.1	17.3	24	0.6417	-9.8	24.2	24	0.6872
Two × *Negotiation*	84.7	26.8	24	0.0043	-92.4	37.0	24	0.0196
s_1	0.0	0.1	400	0.8392	0.1	0.1	400	0.6155
s_1 × *Two*	0.3	0.1	400	0.0088	-0.3	0.1	400	0.0210
s_1 × *Negotiation*	-0.2	0.1	400	0.2516	0.1	0.1	400	0.3977
s_1 × *Two* × *Negotiation*	0.6	0.2	400	0.0001	-0.5	0.2	400	0.0095
s_2	0.0	0.1	400	0.9225	0.0	0.1	400	0.8503
s_2 × *Two*	-0.1	0.1	400	0.1850	0.1	0.1	400	0.6179
s_2 × *Negotiation*	0.2	0.1	400	0.0233	-0.2	0.1	400	0.0768
s_2 × *Two* × *Negotiation*	-0.2	0.1	400	0.1277	0.1	0.2	400	0.3448
			448 Obs.					

†One-sided test.

Table 4. Sum of Estimated Buyer's Surplus and Winning Seller's Surplus, as a Fraction of Expected Maximum Total Surplus

	Homogeneous Products	*Differentiated Products*
Four Sellers First-Price Auctions	96.04%	97.56%
Four Sellers Multilateral Negotiations	97.08%	97.54%
Two Sellers First-Price Auctions	98.40%	97.36%
Two Sellers Multilateral Negotiations	95.45%	98.05%

Instructions for
"Horizontal Product Differentiation in Auctions and Multilateral Negotiations"

Buyer/Auction/Differentiation

<page 1>
This is an experiment in the economics of market decision making. Various foundations have provided funds for this research. The instructions are simple, and if you follow them carefully and make good decisions, you may earn a considerable amount of money that will be paid to you in CASH at the end of the experiment.

In this experiment we are going to create a market in which you will be a buyer of a fictitious good in a sequence of periods.

<page 2>
This is what your screen will look like for the experiment. Notice in the upper left portion of your screen that the row labeled 'Value' has been filled in with numbers. This indicates the value to you of buying a single unit of this good from a particular seller.

Notice that for Seller 1 you have a value of 810 and for Seller 2 the value is 975. You can only buy one unit from one seller each period.

If you're able to buy (we'll describe the selling process soon), you will receive the difference between your value and the price paid (the market price).

To sum up: Value – Price Paid = Profit.

<page 3>
Notice that your cash profits depend upon your ability to buy a unit at a price below the values given on your record sheet. Also note that if you buy a unit at a price equal to its value, your profit will be zero. You cannot buy a unit at price greater than your value.

Your earnings will be automatically entered into your record sheet at the close of each period. Earnings (profits) are accumulated over several periods, with your total earnings at the end of the experiment being your total profit over all periods. The 'Summary Information' frame at the bottom of the screen displays your total profit.

<page 4>
In this experiment there are <insert number of sellers> sellers total, each attempting to sell one unit to 1 buyer. You can only purchase one unit each period.

No seller knows what any of your values are. But, you may ask, "How do I buy this good?" Good question. Continue for the answer.

<page 5>
We will now explain the buying procedures in the following periods. The computer will conduct your buying for you.

Let's go through a sample period. Each seller will submit an offer for a unit to sell to you. An 'offer' is the selling price of the seller.

Once all of the offers have been submitted by the sellers, they will be displayed for you in the 'Seller Offer Prices' in the row labeled 'Price'. In this example, Seller 1 submitted an offer of 600, and Seller 2 submitted an offer of 650.

<page 6>
The computer will choose to purchase from the seller who submitted the offer that yields you your greatest profit. Your record sheet will be filled in as shown for period 1. In this example you purchased a unit from Seller 2 at a price of 650, yielding a profit of 975 – 650 = 325.

In the event that two or more sellers tie for the greatest profit for the buyer, the computer will select a winner at random.

The column labeled 'Market Type' summarizes how the market price was determined that period. In this case, the 'Best Offer' determined the market price.

<page 7>
Let's review the important items:

(1) The seller who submits the offer with the greatest profit for you will be the only person to sell the unit to you, as long as that price is not greater than your value.

(2) The price you pay is equal to that offer of the seller.

(3) Your profit is: Value – Paid.

<page 8>
This is the end of the instructions. If you wish to review the instructions, you may go back at this time. If you feel you now understand the instructions and are prepared to proceed with the actual experiment, click on the 'Start' button. If you have a question that you feel was not adequately answered by the instructions, please raise your hand and ask the monitor before proceeding. Your earnings may suffer if you proceed into the market without understanding these instructions.

Buyer/Multilateral Negotiation/Differentiation

<pages 1-4; same as above>

<page 5>
We will now explain the buying procedures. Your job is to attempt to buy a unit of the good in each period by accepting an offer for it. An 'offer' is the selling price offered to you.

Let's go through a sample period. Each period is comprised of two phases.

Phase 1:
Each seller submits an offer which will be displayed in the row labeled 'Price' in the 'Seller Offer Prices' tab. In this example, Seller 2 submitted an offer for 800.

<page 6>
After all of the offers have been submitted by the sellers, the period advances to **Phase 2**. At any time during Phase 2, you can accept one of the offers and then the period ends. If you accept an offer, then the record sheet will be filled in as shown. The accepted offer will be displayed in the column labeled 'Price Paid' so that you will have a record of the contract prices you accepted.

The rightmost columns in the record sheet will record the history of all the final submitted offers by seller number.

<page 7>
Phase 2 (continued):
Instead of immediately accepting one of the seller's offers, you and the sellers have an opportunity to send messages to each other about a transaction. Messages that you send to a seller (and vice versa) can only be read by you and the seller. You can send private messages to any seller. Sellers can only send messages to you; they cannot send messages to each other.

In the tab in the upper right portion of the screen, you can type your message in the line and click on the 'Send' button.

You are free to discuss all aspects of the market, with the following exceptions: you may not discuss side payments, make physical threats, or engage in inappropriate language and behavior. You may discuss any aspect of the transaction, and you may make agreements with the sellers. However, note that you are in no way bound to the terms of any such arrangements when you actually accept an offer.

At any time, the seller can submit a new offer to you, which you can then accept if you so desire. Hence, you should review the offers carefully to see if they have changed. Sellers must lower their submitted offer. Suppose that Seller 1 lowered his offer to 700. (Seller 1's previous offer was 750.)

The clock in the lower left portion of your screen indicates how much time is remaining in Phase 2 of the period. If you do not accept an offer within the allotted time, you will not purchase a unit that period and your profit will be zero.

<page 8>
The column labeled 'Market Type' summarizes how the market price was determined that period. In this case, 'Negotiations' determined the market price because you had the opportunity to discuss the transaction with the sellers before accepting one offer.

Let's review the important items:

(1) At any time during Phase 2, you may accept the offer of any one seller.

(2) During Phase 2, you can also discuss a transaction with any seller and a seller can submit a new, lower offer.

(3) Your profit is: Value - Price Paid.

<page 9>
This is the end of the instructions. Your earnings in the experiment will be converted into cash at the rate of **<insert exchange rate>** computer dollars for **1 U.S. dollar**. If you wish to review the instructions, you may go back at this time. If you feel you now understand the instructions and are prepared to proceed with the actual experiment, click on the 'Start' button. If you have a question that you feel was not adequately answered by the instructions, please raise your hand and ask the monitor before proceeding. Your earnings may suffer if you proceed into the market without understanding these instructions.

Seller/Auction/Differentiation

<page 1>
This is an experiment in the economics of market decision making. Various foundations have provided funds for this research. The instructions are simple, and if you follow them carefully and make good decisions, you may earn a considerable amount of money that will be paid to you in CASH at the end of the experiment.

In this experiment we are going to create a market in which you will be a seller of a fictitious good in a sequence of periods.

<page 2>
This is your record sheet for the experiment. You can sell at most one unit each period. Notice that you have a cost of 575 for the first period. During the experiment you will only see your cost for the current and past periods.

If you're able to sell (we'll describe the selling process soon), you will receive the difference between the price you receive (the market price) and your cost.

To sum up: Price Received – Cost = Profit.

<page 3>

Notice that your cash profits depend upon your ability to sell a unit at a price above the cost given on your record sheet. Also note that if you sell a unit at a price equal to its cost, your profit will be zero. You cannot sell a unit below your cost.

Your earnings will be automatically entered into your record sheet at the close of each period. Earnings (profits) are accumulated over several periods, with your total earnings at the end of the experiment being your total profit over all periods. The 'Summary Information' frame at the bottom of the screen displays your total profit.

<page 4>
We will now explain the selling procedures. Your job is to attempt to sell a unit of the good in each period by submitting an offer for it. An 'offer' is your selling price offered to the buyer.

Let's go through a sample period. Given your first period cost of 575 you will submit an offer for this unit. Suppose you wanted to sell the unit for 795. To do so, click on the drop down box below the words 'Submit Offer' in the upper left portion of your screen and select the buyer to whom you are willing to make the offer. Then you type 795 in the box below that and click on the 'Submit' button.

Upon submitting the offer, you will be asked to confirm the offer by clicking 'Yes' or 'No'.

<page 5>
After all of the offers have been submitted by the sellers, how are the winning seller and market price determined? Good question, but first here is some information on the buyer(s).

In this experiment there are <insert number of sellers> sellers total, each attempting to sell one unit to 1 buyer. A buyer can only purchase one unit each period.

There is also a maximum amount that a buyer is willing to pay to purchase a unit from a seller.

<page 6>
Once all of the offers have been submitted by the sellers, a buyer will choose to purchase from the seller that yields the greatest profit, as long as the profit is greater than zero. A buyer's profit is Value – Price Paid. If all of the offers are greater than the buyer's values, then the buyer will not purchase a unit that period.

If you submitted the offer that yields the buyer his greatest profit, you will sell a unit and your record sheet will be filled in as shown for period 1. If you do not sell the unit, the column labeled 'Profit' will have a dash entered into it. The offer that the buyer accepted will be displayed in the column labeled 'Market Price,' so that you will have a record of all contract prices.

In the event that two or more sellers tie for the greatest profit for the buyer, the computer will select a winner at random.

The column labeled 'Market Type' summarizes how the market price was determined that period. In this case, the 'Best Offer' determined the market price.

<page 7>
Let's review the important items:

(1) In order to make a profit, your offer must be greater than your cost.

(2) You can change your offer if you have not already confirmed it.

(3) The seller who submits the offer yielding the buyer the highest payoff will be the only person to sell a unit to the buyer.

(4) Your profit is: Price Received – Cost.

<page 8>
This is the end of the instructions. Your earnings in the experiment will be converted into cash at the rate of **<insert exchange rate>** computer dollars for **1 U.S. dollar**. If you wish to review the instructions, you may go back at this time. If you feel you now understand the instructions and are prepared to proceed with the actual experiment, click on the 'Start' button. If you have a question that you feel was not adequately answered by the instructions, please raise your hand and ask the monitor before proceeding. Your earnings may suffer if you proceed into the market without understanding these instructions.

Seller/Multilateral Negotiation/Differentiation

<pages 1-3; same as above>
<page 4>
We will now explain the selling procedures. Your job is to attempt to sell a unit of the good in each period by submitting an offer for it. An 'offer' is your selling price offered to the buyer.

Let's go through a sample period. Given your first period cost of 575 you will submit an offer for this unit.

Phase 1:
Suppose you wanted to sell the unit for 1000. To do so, click on the drop down box below the words 'Submit Offer' in the upper left portion of your screen and select the buyer to whom you are willing to make the offer. For these instructions, choose Buyer 1. Then you type 1000 in the box for your offer and click on the 'Submit' button.

Upon submitting the offer, you will be asked to confirm the offer by clicking 'Yes' or 'No'.

<page 5>
After all of the offers have been submitted by the sellers, the period advances to **Phase 2**. At any time the buyer can accept one of the offers and then the period ends. If the buyer accepts your offer, then the record sheet will be filled in as shown. If you do not sell the unit, the column labeled 'Profit' will have a dash entered into it. The accepted offer will be displayed in the column labeled 'Market Price' so that you will have a record of the contract prices accepted by a buyer.

<page 6>
Phase 2 (continued):
Instead of immediately accepting one of the seller's offers, the buyer and the sellers have an opportunity to send messages to each other about a transaction. Messages that you send to the buyer (and vice versa) can only be read by you and the buyer. However, the buyer can also send private messages to the other sellers. In the tab in the upper right portion of the screen, you can type your message in the line and click on the 'Send' button.

The column labeled 'Market Type' summarizes how the market price was determined that period. In this case, 'Negotiations' determined the market price because the buyer had the opportunity to discuss the transaction with the sellers before accepting one offer.

You are free to discuss all aspects of the market, with the following exceptions: you may not discuss side payments, make physical threats, or engage in inappropriate language and behavior. You may discuss any aspect of the transaction, and you may make agreements with the buyer. However, note that you and the buyer are in no way bound to the terms of any such arrangements when you actually send an offer.

If at any time you would like to submit a new offer to the buyer, you can do so, but the buyer need not accept it. Furthermore, your new offer must be less than your previous offer. You cannot increase your submitted offer.

<page 7>
In this experiment there are <insert number of sellers> sellers total, each attempting to sell one unit to 1 buyer. A buyer can only purchase one unit each period.

There is also a maximum amount that a buyer is willing to pay to purchase a unit from a seller.

<page 8>
Once a buyer accepts an offer from a seller, you can no longer exchange messages with the buyer.

Let's review the important items:

(1) In order to make a profit, your offer must be greater than your cost.

(2) You can change your offer if you have not already confirmed it.

(3) At any time, you can withdraw an offer to 1 buyer and submit one to another buyer.

(4) The buyer can accept at most one offer from a single seller.

(5) Your profit is: Price Received – Cost.

<page 9>
This is the end of the instructions. Your earnings in the experiment will be converted into cash at the rate of **<insert exchange rate>** computer dollars for **1 U.S. dollar**. If you wish to review the instructions, you may go back at this time. If you feel you now understand the instructions and are prepared to proceed with the actual experiment, click on the 'Start' button. If you have a question that you feel was not adequately answered by the instructions, please raise your hand and ask the monitor before proceeding. Your earnings may suffer if you proceed into the market without understanding these instructions.

Handout Read Out Loud to All Participants
(After Subjects Finished Reading the Above Instructions)

Other Information

- There are a total of **<insert number of sellers>** sellers in your market who can sell to a single buyer.
  Throughout the entire experiment, the same **<insert number of sellers>** sellers will be matched with the same buyer.

- Seller costs are assigned randomly. Each seller has an equally like chance of receiving any cost between $0 and $600, inclusive. That is, each seller is equally likely to receive $0, $1, … , $599, $600. All sellers will receive their own random draw each period for their own cost.

- Furthermore, the chance of a seller being assigned any particular cost in this range, for example, 345, is not changed if that cost was assigned earlier to one seller or to another. It is therefore possible for one seller to get the same cost for different periods or for two sellers to have the same cost in the same period.

- The seller's profit is the difference between his/her cost and the price received, or Price received - cost = Seller's Profit.

- <if *Differentiation* Treatment> The buyer value has a different randomly assigned value for each seller each period. The value for a particular seller has an equally like chance of being between $300 and $900, inclusive. That is, each value is equally likely to be $300, $301, … , $899, $900.

- The buyer's profit is the difference between his/her value and the price paid, or Value - Price paid = Buyer's Profit.